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IS THERE A 'BEST' SAWING METHOD

FOREST PRODUCTS LABORATORY
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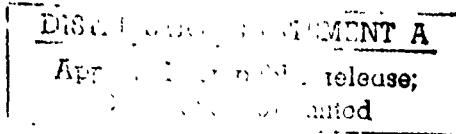
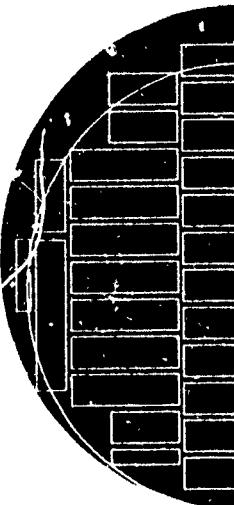
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ABSTRACT

The Best Opening Face (BOF) computer sawing program has been used to investigate the relationship, in terms of lumber yield, of log diameter (5 to 20 in.), log length (8 to 24 ft.), and taper (1 to 5 in.) to eight of the most commonly used sawing methods.

Results generally show that logs 16 feet or shorter and with 3 inches or less of taper, yield best when sawn by one sawing method, and those longer and with more taper by another method.

Results of this research can form the basis for making rational selection of sawing systems in new mills when the log mix to be processed is known.

As examples of the potential of this information in management decisions, three actual sawmill log mixes were analyzed in terms of expected yields by each of the sawing methods.



IS THERE A "BEST" SAWING METHOD?

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INTRODUCTION

A large number of factors affects the volume of lumber obtained from any given log by the sawing process. These factors are of two different types. The first are those commonly recognized as kerf width, rough lumber target size, smallest lumber allowed, and slabbing and edging practices. The second are the differences in the log breakdown patterns. The effects of the first factors are logical and predictable and are relatively easily understood. The second interact less predictably with log form and size. These are not easily understood and their effect on the volume of lumber obtained is not apparent from casual consideration.

Logs may be live sawn (through and through in one plane) or they may be cant sawn (side lumber and cant in one plane with the cant further broken down in a second plane normal to the first). In addition, they may be sawn split-taper (parallel to their central axis) or full-taper (parallel to one of the outside faces of the log). In the case of cant sawing, the cant developed may be sawn full-taper or split-taper. Further, when the cant is full-taper sawn, the location of the opening face can be fixed or variable. Thus, six basically different breakdown patterns exist, with two variations for

full-taper sawing the cant, making a total of eight (fig. 1).

These eight patterns are: live, split-taper (live ST); live, full-taper, (live FT); cant, split-taper-split-taper (STST); cant, full-taper-split-taper (FTST); cant, split-taper-full-taper-fixed fence (STFTF); cant, full-taper-full-taper-fixed fence (FTFTF); cant, split-taper-full-taper-variable fence (STFTV); and cant, full-taper-full-taper-variable fence (FTFTV).

Many arguments have been advanced to support one or another of these systems. Proponents of live sawing point out that it generates fewer sawlines and less sawdust than does cant sawing, resulting in a higher potential for lumber recovery. Cant sawing supporters argue that in live sawing, all taper in the plane normal to the board faces is lost in edgings, while in cant sawing, some of this material can be saved as short boards. Some believe full-taper promises higher yields since the possibility of an additional piece of lumber from the log is better if all the taper is thrown to one sawing face rather than divided between two opposite faces. Supporters of split-taper feel it is best because it produces less radically tapered side lumber and cants with a more balanced form. There is logic in all of these

¹Maintained at Madison, Wis., in cooperation with the University of Wisconsin

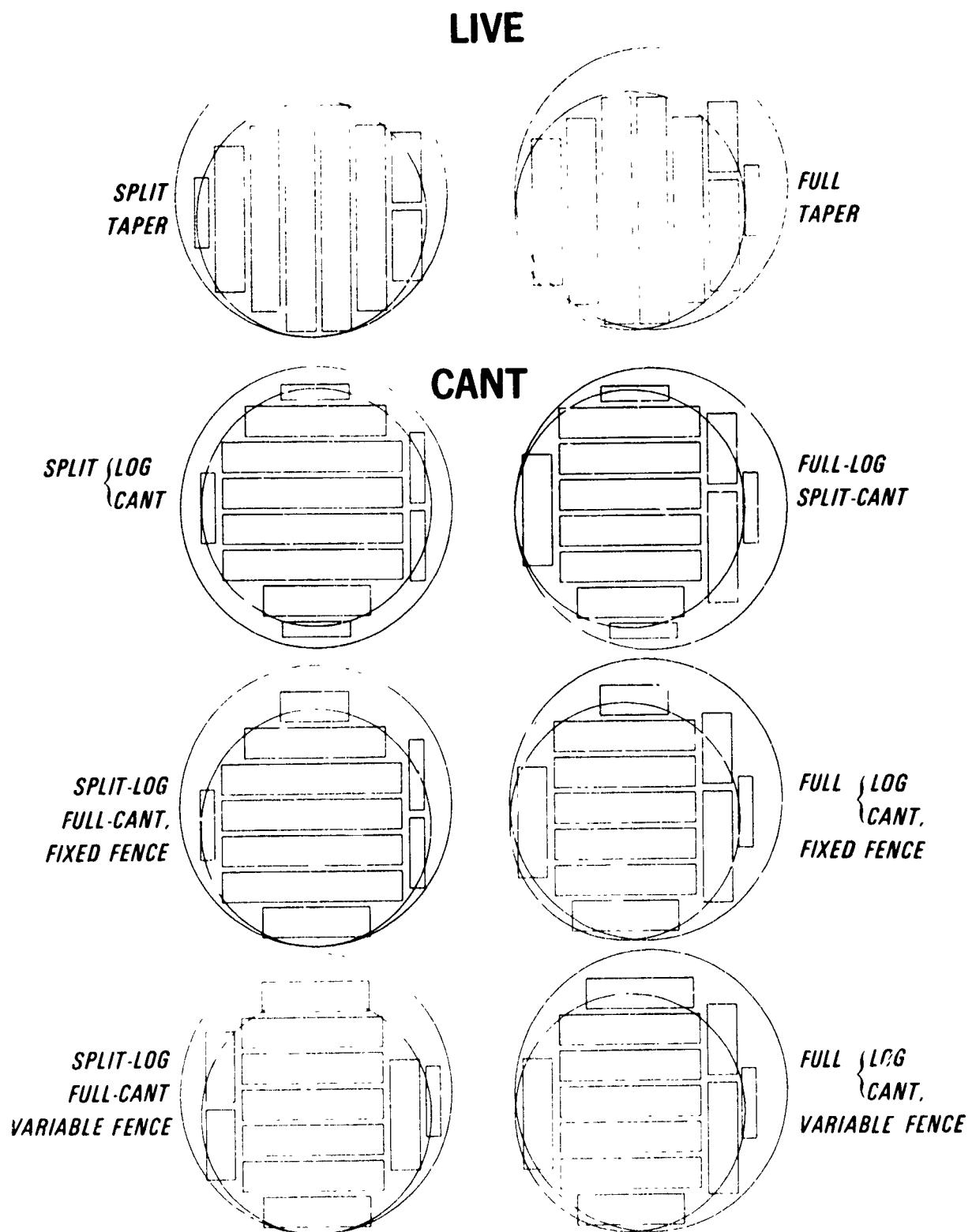


Figure 1. -- The eight sawing methods and the BOF solutions for a 12.2-inch-diameter, 20-foot-long log with a taper of 1.8 inches per 16 feet

(M 144 221)

arguments but evidence of their validity is lacking.

Most mill managers have a reasonably good knowledge of the lengths, diameters, and taper of logs processed in their mill. Knowing which log breakdown pattern or patterns promise the best lumber yields could help managers to choose mill equipment and layout that could best implement those patterns.

The recent development of the Best Opening Face (BOF) computer sawing program,^{2, 3, 4} which simulates any of the previously mentioned log breakdown methods, has made possible a systematic analysis of the various sawing alternatives. The BOF program finds the sawline placement resulting in the maximum yield for any specific log when sawn by a given set of actual or hypothetical sawing conditions. Thus, by specifying all of the sawing conditions and using the BOF program on a given range of log diameters, lengths, and tapers, the best breakdown pattern can be determined for each situation.

PROCEDURE

The logs studied were of a size commonly converted to softwood dimension lumber in so-called "small log" mills. They ranged in diameter from 5.2 to 20.6 inches by 0.2-inch increments; in length from 8 to 24 feet by 2-foot increments, and in taper from 1 to 5 inches per 16-foot length by 1-inch increments. All of the 3,510 possible log combinations were computer-sawn -- i.e., by the mathematical modeling of the sawing process -- by each of the eight breakdown patterns shown in figure 1.

In addition to the sawing of a uniform array of log diameters, three actual log distributions were selected from the several hundred SIPs studies completed by the U.S. Forest Service during the last 2 years. These distributions (fig. 2) were selected to represent different popula-

²Hallock, H., and D W Lewis 1971 Increasing softwood dimension yield from small logs USDA For Serv. Res Pap FPL 166 For Prod Lab, Madison, Wis

³Hallock, H., and D W Lewis 1973 Best Opening Face for Second-Growth Timber Chap 4 In Modern Sawmilling Techniques, Vol 1 Proc of the First Sawmill Clinic, Portland, Oreg., Feb 1973 Miller-Freeman Publications, Inc., San Francisco, Calif

⁴Lewis, D W and H Hallock 1974 Best Opening Face Programme Austral For Ind J 40(10) 21-23, 25, 27, 29-31

tions of logs with respect to diameter and length. All logs in each distribution were sawn by all eight sawing methods.

Conditions specified in the BOF simulation were as follows: All lumber was edged full length of the flitch allowing a maximum of 25 percent wane according to the National Grading Rule.⁶ The smallest piece of lumber sawn was 4 inches wide and 8 feet long. The setting increments were 1/16 inch. Headsaw kerf (vertical) was 0.165 inch. Cant breakdown kerf (horizontal) was 0.134 inch. Sawing variation ranged from 0.063 to 0.125 inch (table 2). When sawing with a fixed fence on full-taper sawn cants, the BOF program positioned the fence for 4-inch and 5-inch cants such that a nominal 4-inch by 8-foot face with maximum allowable wane would be produced if the cant had come from a log of 4.5 inches in diameter. On cants 8 inches and larger, the fence position was such that the 4-inch by 8-foot face would be produced if the cant had come from a log of 8.8 inches in diameter. These two log diameters are the smallest that will produce an acceptable 4-inch and 8-inch cant with the sawing conditions used.

Both 4/4-inch and 8/4-inch lumber were cut in the vertical plane but for both full- and split-taper, the 4/4 was limited to the first cut on the log and possibly the last cut, if in so doing the recovery was higher than would result from 8/4. On the cant (horizontal plane) for full-taper cant sawing, the 4/4 was limited to the last cut opposite the opening face if it proved advantageous as compared to a final 8/4 cut. All other lumber was 8/4. Widths cut were nominally 4, 6, 8, 10, and 12 inches. The actual widths and thicknesses cut, together with dressing allowances, shrinkage, and sawing variation, are shown in table 2.

When cant sawing, the BOF program tried all possible cant sizes for each log. Four- and six-inch cants had to yield at least two pieces of 8/4, while 8-, 10-, and 12-inch cants had to yield at least three pieces of 8/4. The cant size giving the highest board-foot yield was selected.

⁵SIP refers to the Sawmill Improvement Program. During the past 2 yr., the State and Private Forestry branch of the U.S. Forest Service, in cooperation with state forestry agencies, has conducted more than 500 conversion efficiency studies at softwood mills making dimension lumber from small logs

⁶U S Department of Commerce American Softwood Lumber Standard Prod Stand PS 20-70 (See current edition)

RESULTS

The total board-foot yields that resulted from sawing one of the original study logs of each combination of diameter, length, and taper are summarized in the first columns of table 1. In addition, the best total yield is shown. The best total is the total yield that would result if each log were sawn by the best of the eight sawing systems. Also shown for each method is the percentage of the best total yield that would have been obtained had all the logs been sawed by that method.

The summary presented in table 1 is somewhat biased in that it assumes a log distribution which is uniform across its entire range -- a condition probably never existing in nature. Recognizing this limitation, it is still worth noting that cant-sawing methods on the average yielded about 3 percent more lumber than live sawing (98.8 vs. 96.0 pct). The best

cant-sawing method yields 3.6 percent more than the poorest live sawing method. Live sawing gave the maximum yield on only 56 of the 3,510 logs.

Completely ignored in a summary of this type is the possibility that diameter, length, or taper might influence the yield differently in some sawing methods than in others. To examine this possibility, two cant-sawing methods were chosen -- split-taper-full-taper-fixed fence, and full-taper-full-taper-fixed fence. These two were chosen because they are the two most widely used industry methods for converting small logs to dimension lumber. Also, the difference in total yield for the entire range of logs is very slight (0.04 pct). To reduce the log sample size to a level such that the results could be presented graphically or in tabular form, the yields from diameters from 5.2 through 19.0 inches were combined into 2-inch classes.

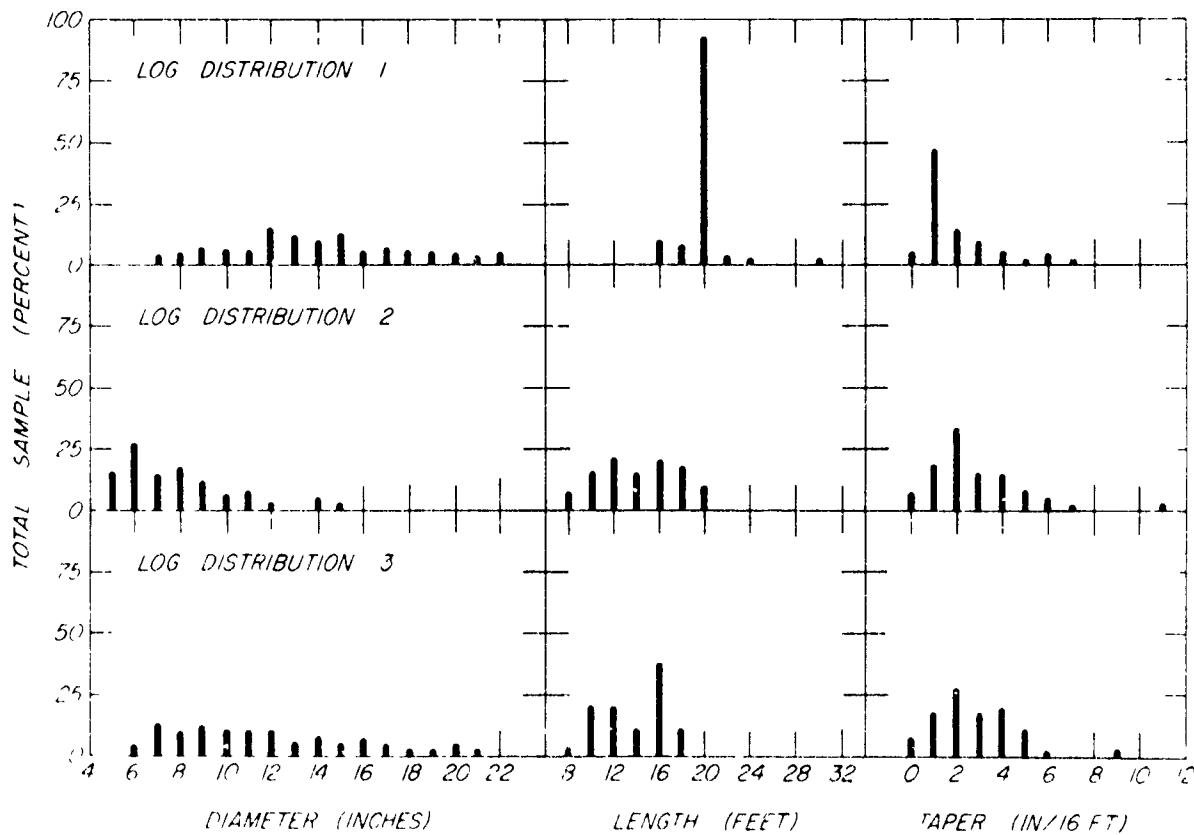


Figure 2 -- The size and form of the logs represented in the three "real log" samples obtained from SIP studies

Table 1. -- Yield (board feet and percent of best total) for groups of logs sawn by eight BOF sawing methods

Sawing method	Original study logs		Log Distribution 1		Log Distribution 2		Log Distribution 3	
	Total	Percent of best total	Total	Percent of best total	Total	Percent of best total	Total	Percent of best total
	<u>Bd ft</u>	<u>Bd ft</u>	<u>Bd ft</u>	<u>Bd ft</u>	<u>Bd ft</u>	<u>Bd ft</u>	<u>Bd ft</u>	<u>Bd ft</u>
<u>Live</u>								
ST ¹	734,592	95.52	28,025	95.56	6,219	93.80	14,364	94.44
FT ²	742,295	96.53	28,369	96.73	6,345	95.70	14,619	96.12
<u>Cant</u>								
STST ³	754,840	98.16	28,771	98.10	6,401	96.55	14,909	98.02
FTST ⁴	761,620	99.04	29,104	99.24	6,509	98.17	15,118	99.40
STFTF ⁵	758,193	98.59	28,868	98.43	6,439	97.12	14,928	98.15
FTFTF ⁶	758,462	98.63	29,037	99.01	6,482	97.77	15,050	98.55
STFTV ⁷	762,093	99.10	29,017	98.94	6,500	98.04	15,010	98.69
FTFTV ⁸	762,294	99.13	29,169	99.45	6,525	98.42	15,132	99.49
Best Total ⁹	769,013	--	29,327	--	6,630	--	15,209	--

¹Split-taper.

²Full-taper

³Split-taper on log, split-taper on cant

⁴Full-taper on log, split-taper on cant

⁵Split-taper on log, full-taper on cant, cant sawn against fixed fence

⁶Full-taper on log, full-taper on cant, cant sawn against fixed fence

⁷Split-taper on log, full-taper on cant, cant sawn against variable fence

⁸Full-taper on log, full-taper on cant, cant sawn against variable fence.

⁹Total yield that would result if each log were sawn by the method giving highest yield for that log.

Table 2. -- Lumber sizes and sizing factor values

Dimension	Nominal	Dry dressed	Dressing allowance ¹	Shrinkage	Sawing variation	Rough green
Thickness				in.		
	1	0.750	0.121	0.027	0.063	0.960
	2	1.500	.098	.049	.063	1.710
Width						
	4	3.500	.153	.113	.109	3.875
	6	5.500	.153	.175	.109	5.938
	8	7.250	.146	.229	.125	7.750
	10	9.250	.147	.291	.125	9.813
	12	11.250	.148	.352	.125	11.875

¹Dressing allowances vary because of the necessity of having rough green thickness plus one kerf be a multiple of the 1/16-in setting increments. In the case of widths, the width (without kerf) must be a 1/16-in multiple. Wood added to obtain the 1/16-in multiple is removed in the dressing operation.

Figure 3 shows the effect of length and taper on yield and the effect of the interaction between length and taper on yield when diameters are pooled. No difference occurs in the 8-foot length simply because no lumber shorter than 8 feet was salvaged, so the opportunity for differing recovery between these two systems simply did not exist. Had 4- or 6-foot lumber been salvaged, some difference would have been evident.

Logs in all five taper classes give higher yields by the FTFTF method than by the STFTF method in the shorter lengths. The difference between the two methods increases with

length to a point and then declines till the STFTF method becomes better. With further increases in length, the difference in favor of STFTF continues to increase. Within the range of lengths examined, the crossover does not occur in the 1- and 2-inch-taper classes although indications are (fig. 3) that it would probably do so with lengths above 24 feet. Logs in the 3-inch-taper class show better yields if sawn by STFTF if they are at least 24 feet in length; in the 4-inch-taper class, when 18 feet or longer; and in the 5-inch-taper class, when 16 feet or longer. Actual differences in yield by these two methods when diameters

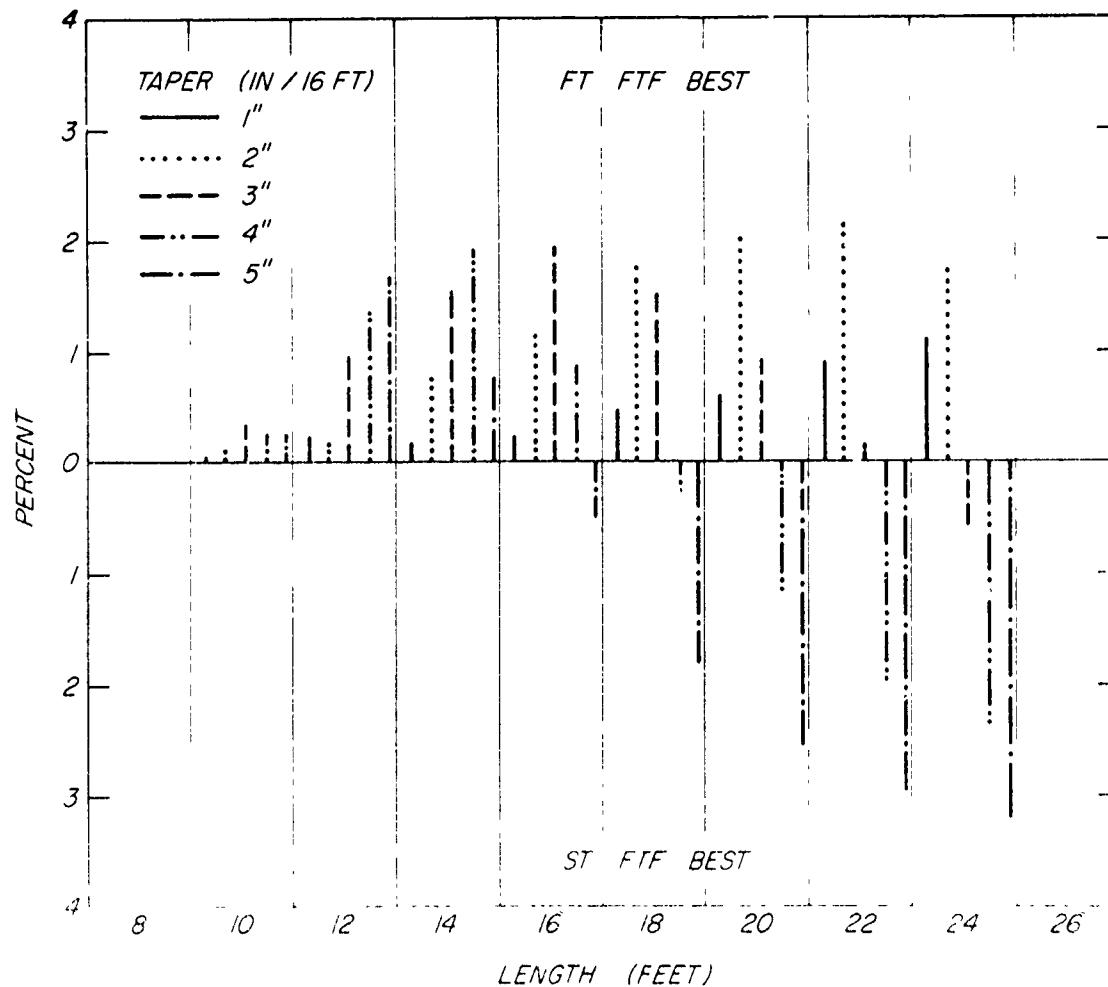


Figure 3 -- The relationship of log length and taper to yields when logs are sawn FTFTF and STFTF. Bars above the 0 percent line indicate for which log lengths and tapers the full-taper-full-taper-fixed fence method (FTFTF) is best, and those below show for which logs the split-taper-full-taper-fixed fence (STFTF) method is best.

$$\text{Percent} = \frac{\text{Best method} - \text{poorest method}}{\text{Best total}} \times 100$$

(M 144 269)

are pooled range from less than 0.1 percent for 10-foot, 1-inch-taper-class logs, to more than 3 percent for 24-foot, 5-inch-taper-class logs.

The relationship of yield by the two sawing methods to log diameter and taper class was determined with all lengths pooled (fig. 4). Logs in the 6- through 18-inch-diameter class within the 1-inch-taper class and logs 8 through 18 inches within the 2-and 3-inch-taper classes yield better when sawn by the FTFTF method. Logs 6 inches in diameter

within the 2-, 3-, 4-, and 5-inch-taper classes and 8- through 18-inch logs in the 4- and 5-inch-taper classes are better sawn by the STFTF method. The trends seem to indicate that diameters larger than 18 or 20 inches would probably best be sawn by the STFTF method.

Differences in yield by the two sawing methods when lengths are pooled range from less than 0.3 percent for 10-inch logs in the 4-inch-taper class to more than 4 percent for 6-

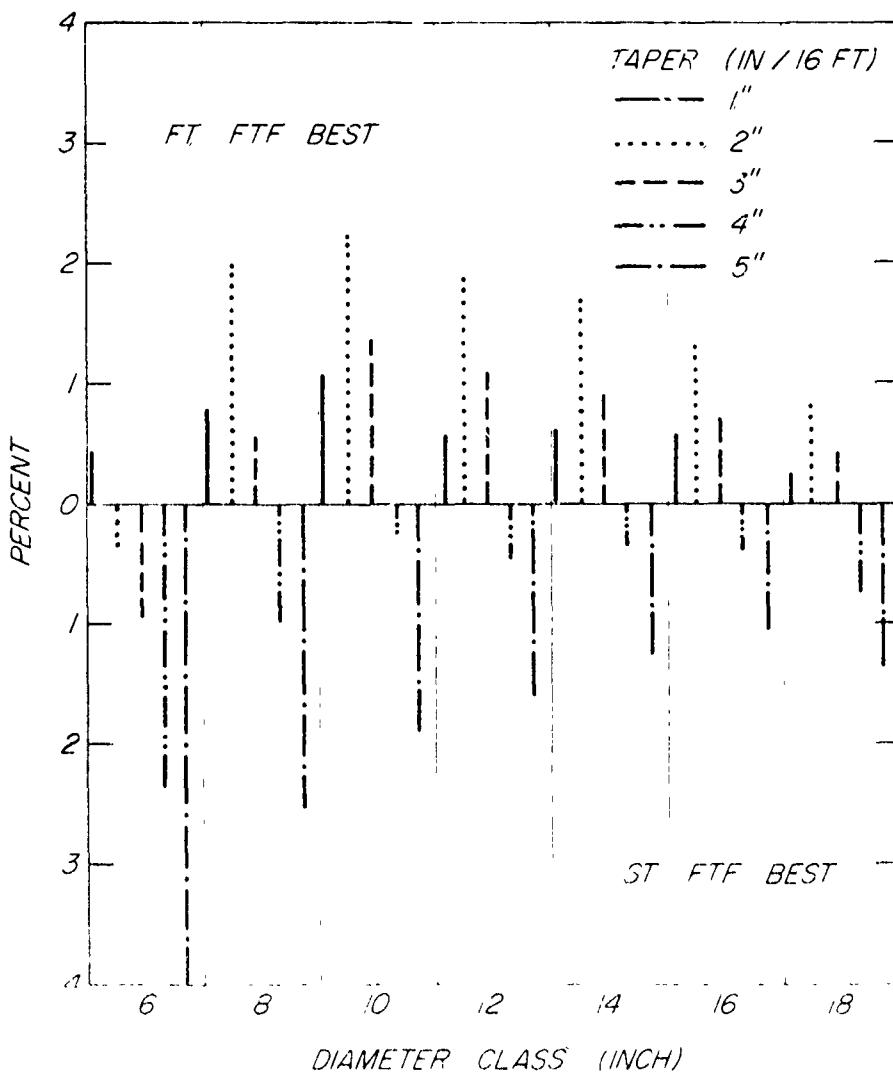


Figure 4 -- The relationship of log diameter and taper to yield when logs are sawn FTFTF and STFTF. Bars above the 0 percent line indicate for which log lengths and tapers the full-taper-full-taper-fixed fence method (FTFTF) is best, and those below show for which logs the split-taper-full-taper-fixed fence (STFTF) method is best

$$\text{Percent} = \frac{\text{Best method} - \text{poorest method}}{\text{Best total}} \times 100$$

(M 144 267)

inch logs in the 5-inch-taper class.

The general trend that shorter, low-taper logs are better sawn by FTFTF and longer, higher taper logs by STFTF was observed in both the length and diameter analyses. Full-taper sawing of the log has the potential to yield more side lumber since all the taper is thrown to one side and the possibility of recovering short lumber from this taper is increased. However, this is relatively more important in the shorter logs because in longer logs, even though the taper is split half on each side, there is sufficient stock in each half of the taper to yield short lumber. When logs are full-taper sawn, a cant is produced which tends to have one sawn face nearly equal in width the full length and substantially different in width at the two ends of the opposite face. In some cases the widest end of each of the two faces is on opposite ends of the cant. For either of these cant forms, the lumber recovery factor (ratio of board feet of lumber to cubic feet of cant) will inevitably be lower than from a cant resulting from a log sawn split-taper where both faces are about the same. The disparity between cant faces from a full-taper-sawn log increases both with length and log taper.

Thus, a situation exists in shorter, low-taper logs where the loss in cant lumber recovery is more than offset by increased side lumber recovery. In longer, higher taper logs, the difference in increased side lumber recovered from the log by the full-taper method is reduced at the same time that the losses in cant conversion from the same method are increased and the overall result is a change in favor of split-taper sawing the log.

The results of the four-way interaction between diameter, length, taper, and the most common industry sawing methods are expressed as the method that gave the highest yield (table 3). When expressed in this manner, the pattern of "which sawing method is best" across all variables is about as would be expected by observing the trends in figures 3 and 4, indicating little interaction between diameter and length. It is interesting to note that almost all 6-inch-diameter-class logs are best sawn by the STFTF if their taper exceeds 1 inch, even though this does not follow the general pattern evident in the table. This can be explained by the fact that the minimum-width lumber (4 in.) is only a little smaller than the log cross-section. This accentuates the

problem of geometrical fit in the nonsymmetrical cant that results from full-taper sawing the log. If 2- and 3-inch-wide lumber had been specified as acceptable in the BOF runs, it is probable that the 6-inch diameter would have conformed to the fairly well defined trends evident in the rest of the table.

The results of sawing logs from the real log distributions obtained from three SIP studies by all eight sawing methods are presented in table 1. In all cases no single method yielded recoveries as high as would be possible if all methods were available to the mill on an individual log basis. For all log mixes studied, poorest recoveries resulted from live ST sawing and best yields were obtained when the FTFTV method was used. None of the log mixes contained a sufficient number of long, high-taper logs to make overall yields best by the STFTF or STFTV methods.

Actual differences between yields by industry's two most popular sawing methods, STFTF and FTFTF, were 0.58, 0.65, and 0.80 percent for Log Distributions 1, 2, and 3, respectively. Although not shown in the tables, it is interesting to note the contribution of live sawing to "best total" in each of the log distributions. Live sawing gave highest total yields in 1 percent of Log Distribution 1, 12 percent of Log Distribution 2, and 4 percent of Log Distribution 3.

Another difference in potential yield from these log mixes is of interest to mill planning. An increase can be expected by having, at the rotary gang, a movable fence positionable at the desired distance from the first saw compared to a fixed fence. This difference ranged from 0.44 percent for Log Distribution 1 sawn by full-taper-full-taper to 0.92 percent for the split-taper-full-taper sawing of Log Distribution 2.

It should be recognized, however, that this difference is substantially less than would occur if randomly developed cants had been sawn. The BOF program, in solving for the best sawline position for either of the fixed-fence methods, will automatically produce a cant whose best sawing solution includes an opening face on the cant in the position produced by the fixed fence. In sawing with a variable fence, this constraint is removed and, in many cases, slightly better solutions are found.

Table 3. -- Best of two sawing systems¹ for all combinations of log length, diameter, and taper

Taper	Diameter class	Length								
		8	10	12	14	16	18	20	22	24
<u>In./16 ft.</u>	<u>In.</u>	<u>Ft.</u>								
1	6	—	F	—	—	F	F	F	F	F
	8	—	—	—	F	F	F	F	F	F
	10	—	F	F	F	F	F	F	F	F
	12	—	—	F	F	F	F	F	F	F
	14	—	—	F	F	F	F	F	F	F
	16	—	—	—	F	S	F	F	F	F
	18	—	—	F	F	S	F	F	F	F
2	6	—	—	S	—	F	S	F	S	S
	8	—	—	S	F	F	F	F	F	S
	10	—	—	F	F	F	F	F	F	F
	12	—	—	F	F	F	F	F	F	F
	14	—	—	S	F	F	F	F	F	F
	16	—	—	S	F	F	F	F	F	F
	18	—	—	S	F	F	F	F	F	F
3	6	—	—	S	—	S	S	S	S	S
	8	—	—	S	F	F	F	F	F	S
	10	—	—	F	F	F	F	F	F	S
	12	—	—	F	F	F	F	F	F	S
	14	—	—	F	F	F	F	F	F	S
	16	—	—	F	F	F	F	F	F	S
	18	—	—	F	F	F	F	F	F	S
4	6	—	—	S	S	S	S	S	S	S
	8	—	—	F	F	F	F	F	F	S
	10	—	—	F	F	F	F	F	F	S
	12	—	—	F	F	F	F	F	F	S
	14	—	—	F	F	F	F	F	F	S
	16	—	—	F	F	F	F	F	F	S
	18	—	—	S	F	F	F	F	F	S
5	6	—	—	S	S	S	S	S	S	S
	8	—	—	F	F	F	F	F	F	S
	10	—	—	F	F	F	F	F	F	S
	12	—	—	F	F	F	F	F	F	S
	14	—	—	F	F	F	F	F	F	S
	16	—	—	F	F	F	F	F	F	S
	18	—	—	S	F	F	F	F	F	S

¹Full-taper-full-taper-fixed fence (FTFTF) and split-taper-full-taper-fixed fence (STFTF)

F - FTFTF is best.

— - No difference.

S - STFTF is best.

RECOMMENDATIONS TO INDUSTRY

It is recognized that the BOF computer sawing program gives yields higher than can be obtained from real logs. However, there is every reason to believe that the relationships among the various sawing methods with respect to the log variables are valid. In addition, the size of indicated differences in yield should also be valid. Likewise, although changes in such values as kerf width, setting increment, etc., will affect the actual recoveries from individual logs, these changes will not alter the relationships among the sawing methods.

Every mill operates on a different mix of

logs. The capability to saw by more than one of the eight sawing methods represents additional investment in equipment (except for the conventional carriage system). Consequently, as much precision as possible is desirable in the estimate of yield increases promised by increased flexibility of sawing methods. With this in mind -- especially for those who are actually involved in the choice of sawing system decisions -- we have available the basic individual log yield data for all 3,510 log sizes sawn by each of the eight methods. The publication, "Individual Log Yields by Eight Sawing Systems," makes it possible to determine for any specific log mix the exact relationship of all of the sawing systems or any combination. Use of the data it contains will take the investment decisions on choice of sawing method out of the realm of guessing.

SUMMARY

This study was conducted to investigate the relationship of log diameter (5 to 20 in.), log length (8 to 24 ft.), and taper (1 to 5 in. per 16 ft.) to dimension lumber yields by eight sawing systems. Such information is of value in the planning of sawmills for sawlog resources whose parameters are known.

Logs were computer-sawn -- i.e., by the mathematical modeling of the sawing process -- by the BOF program to include all combinations of length, diameter, and taper; 3,510 logs were sawn. This program was used to find the best yield by each of the eight sawing systems. Results were analyzed to establish basic relationships between the log factors, sawing methods, and yields.

Although some individual logs give better

yields by one of the two live-sawing methods, the overwhelming majority are better sawn by any one of the six cant-sawing methods.

Shorter logs (less than 16 ft.) with taper of 3 inches or less per 16 feet are best cant sawn using full-taper on the log and 'ull-taper on the cant. Longer (over 16 ft.), higher taper logs (over 3 in.) are best cant sawn using split-taper on the log and full-taper on the cant. For both these trends, some additional recovery results from using a variable fence as opposed to a fixed fence when sawing the cant.

Best yields will result in any real situation if the mill has the capability to select from all eight sawing methods on an individual log basis. The margin of the advantage can vary between about 0.5 percent and 6.6 percent depending on log mix and the actual single system with which the combination is being compared.

A supplement to this paper, "Individual Log Yields by Eight Sawing Systems," is available from the U.S. Forest Products Laboratory. The publication contains the basic information generated by the BOF sawing of all logs by all methods. Its use by mill management is strongly recommended for determining the actual yield relationships by the different sawing methods when they are applied to a known log mix.